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# Functional Requirements in Designing Dairy Barns

By T. A. H. Miller, *senior agricultural engineer*, George L. Edick, *chief draftsman*, and Wallace Ashby, *principal agricultural engineer and head, Division of Farm Structures, Bureau of Plant Industry, Soils, and Agricultural Engineering*, and James R. Dawson and Thompson E. Woodward, *senior dairy husbandrymen, Division of Breeding, Feeding, and Management, Bureau of Dairy Industry, Agricultural Research Administration*[1]

## CONTENTS



TO AID IN THE DESIGN of more satisfactory farm buildings, the Agricultural Research Administration, United States Department of Agriculture, with the cooperation of the State agricultural experiment stations, is preparing descriptions of the functional requirements of buildings for farm animals. This circular on dairy barns is the second of the series.[2] State agencies using this material in educational and construction programs may wish to supplement it with more detailed statements applying to their areas.

[1] The preliminary draft of this circular was prepared by K. E. Parks, Bureau of Dairy Industry; J. L. Strahan, Farm Security Administration; and the late M. A. R. Kelley, Bureau of Plant Industry, Soils, and Agricultural Engineering.

[2] The first publication in the series was Circular 701, Hog-Housing Requirements, 16 pp., illus. 1944.

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So far as possible the requirements are stated in terms of space to be provided or function to be performed and do not specify any particular material for the buildings, as it will be possible to apply many war developments in the use of materials in post-war farm construction.

## SOURCES OF INFORMATION

The design of buildings for dairy cows involves a number of technical problems on which basic information is lacking. This circular presents a summary of present-day opinions of dairy and building specialists of the State agricultural colleges and of the United States Department of Agriculture. Before facts instead of opinions can be presented, much research on many phases of housing dairy cows will be needed. Some of the recommendations here presented may not be applicable in all States, and where that is the case the advice of local specialists should be sought.

## THE DAIRY COW AND HER HABITS

Hundreds of years of selection and breeding have developed the modern, highly specialized cow whose primary function is to produce milk for human use. A yield of 10,000 pounds (1,162 gallons) of milk a year for one cow is not uncommon, and a few individuals have produced approximately 40,000 pounds (4,650 gallons). The characteristics and habits of the dairy cow, as well as sanitary requirements for the production of milk for human food, must be considered when designing dairy barns.

The cow's digestive system enables her to utilize large quantities of roughages, and as these are usually the cheapest source of nutrients the design of the dairy barn should provide facilities for storing and for feeding large quantities of hay, silage, and other roughages.

The dairy cow is rather slow moving and normally exercises only as required to obtain food. Since she spends most of her time lying down and chewing her cud, a good bed of straw is important for her comfort and aids in keeping her clean. Her hoofs are adapted for walking on soft ground; she has difficulty keeping her footing on smooth surfaces, frequently injuring herself by slipping on ice and wet floors. A cow is a creature of habit and is usually easily managed unless frightened or abused. Milking and feeding therefore should be done regularly, and the barn should be designed for quiet systematic work.

A dairy cow will adapt herself to great differences in climate, but thrives and produces best in cool regions. She grows a long coat of hair for protection and stands moderately cold weather without discomfort if sheltered from rain, snow, and cold winds. A cow perspires very little, and her normal body temperature of 101° to 102° F. is controlled largely by evaporation of moisture from the respiratory organs and the muzzle. She appears to suffer as much as a man, or even more, under conditions of high temperature and high relative humidity.

Probably as a result of close confinement in large numbers the dairy cow is subject to many diseases and infections, the most important of which, from the standpoint of their relation to man, are tubercu-

losis, brucellosis (Bang's disease), and mastitis. The newborn calf, which is usually separated at 1 or 2 days of age from the cow and then fed milk by hand, also is especially subject to digestive disturbances (scours) when the milk is fed from insanitary pails. If exposed to low temperatures, dampness, or drafts, the calf may contract pneumonia. Elimination of unfavorable conditions therefore is an important feature of dairy-barn design.

## DISTRIBUTION OF DAIRY COWS IN THE UNITED STATES

The number of farms in different sections of the United States reporting in the 1940 census on the number of cows kept for milk is shown in table 1. It is interesting to note that about 68 percent of all farms keeping cows and about 93 percent of those in the South Atlantic States have less than five dairy cows each. In 1939, 64 percent of all milk in the United States was produced in the Middle Atlantic, East North Central, and West North Central States; of this, 28 percent was produced in the East North Central States. Wisconsin alone produced 11.5 percent of all milk, which was 52 percent more than the next highest State.

## GENERAL CONSIDERATIONS

A good dairy barn should provide: (1) Conditions favorable to the productivity, health, and safety of the animals; (2) all necessary sanitary safeguards surrounding the production of milk; (3) facilities and arrangement for economical use of feed and labor; and (4) safe, healthful conditions for workers. These requirements should be met at the minimum expense consistent with sound building construction.

To attain these objectives certain principles of design that are basic for almost any permanent structure should be followed. It is necessary to protect the building from destruction by fire and from deterioration and damage by breakage, rodents, termites, and dampness. In some regions, the effects of wind, lightning, heavy snows, and unfavorable soils become special factors influencing design. All buildings should be constructed in a workmanlike manner, of materials suitable for the particular use, and with observance of principles of good design, safety, and the sanitary codes.

### Building Requirements as Modified by Climate

Regional differences in climate influence the system of stabling dairy cows, particularly as regards space requirements and building details. The average number of hours of winter sunshine and the average relative humidity in January in different parts of the country are shown in figures 1 and 2, respectively. Average January temperatures and temperature zones are shown in figure 3. The 35° F. isotherm forms the boundary between zones 2 and 3; the 50° isotherm between zones 3 and 4. Since heat losses from barns by conduction and ventilation are smaller in areas of low humidity and much sunshine, the boundary between cold zones 1 and 2 has been adjusted to take account of the effect of high relative humidity in increasing heat

TABLE 1.—*Number of farms reporting cows and heifers for milk production, by geographic divisions, April 1, 1940*

| Division | Total number of farms reporting | Number of farms by number of cows in herd | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1–4 | 5–9 | 10–14 | 15–19 | 20–29 | 30–49 | 50–74 | 75–99 | 100–199 | 200 and over [1] |
| New England | 86,620 | 47,188 | 13,954 | 9,749 | 6,111 | 6,130 | 2,788 | 503 | 109 | 80 | 8 |
| Middle Atlantic | 251,276 | 115,909 | 50,532 | 35,382 | 20,995 | 18,963 | 7,904 | 1,193 | 212 | 155 | 31 |
| East North Central | 832,353 | 394,117 | 251,173 | 106,106 | 47,092 | 27,292 | 5,894 | 518 | 90 | 62 | [2] 9 |
| West North Central | 929,545 | 415,393 | 339,575 | 122,327 | 34,969 | 14,375 | 2,488 | 301 | 66 | 43 | 8 |
| South Atlantic | 698,364 | 647,487 | 32,539 | 8,051 | 3,657 | 3,411 | 2,165 | 617 | 209 | 179 | 49 |
| East South Central | 770,473 | 704,679 | 48,322 | 9,411 | 3,228 | 2,611 | 1,546 | 430 | 117 | 113 | [3] 16 |
| West South Central | 758,952 | 620,304 | 107,728 | 19,104 | 4,798 | 3,602 | 2,197 | 709 | 202 | 256 | 52 |
| Mountain | 160,994 | 103,543 | 39,104 | 11,469 | 3,420 | 2,173 | 951 | 214 | 58 | 51 | 11 |
| Pacific | 155,740 | 101,828 | 24,881 | 10,712 | 5,432 | 5,365 | 4,170 | 1,835 | 659 | 681 | 177 |
| United States | 4,644,317 | 3,150,448 | 907,808 | 332,311 | 129,702 | 83,922 | 30,103 | 6,320 | 1,722 | 1,620 | 361 |

[1] Average herd over 300 except where noted.

[2] Average herd 285.3.

[3] Average herd, 256.9.

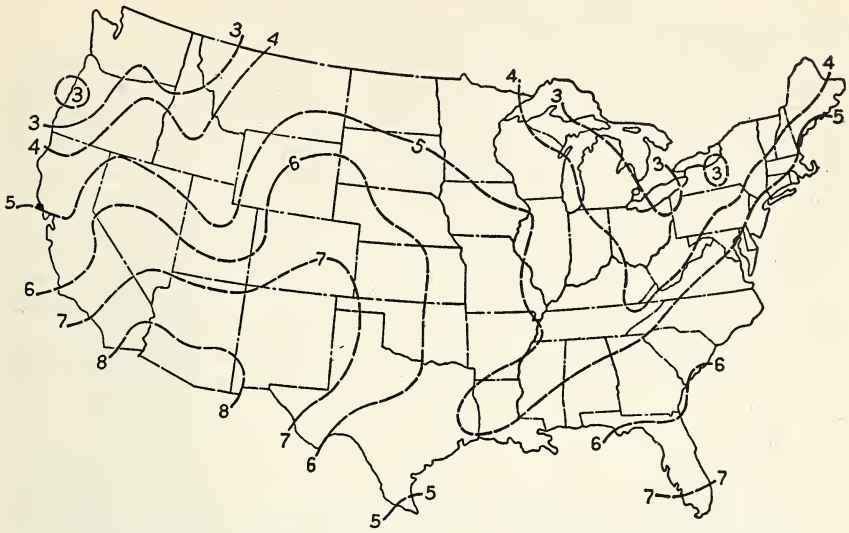


FIGURE 1.—Average number of hours of sunshine daily during winter, December, January, and February.

loss by ventilation. Where the relative humidity is 70 percent, the zone boundary coincides with the 20° isotherm; where it is 80 percent, the boundary approaches the 25° isotherm.

Minimum temperatures of about 40° F. below the January average may occur once or twice a year in most of zones 1 and 2, except along the west coast. In zones 3 and 4 the annual minimum temperatures are usually about 30° below the January average. The average tem-

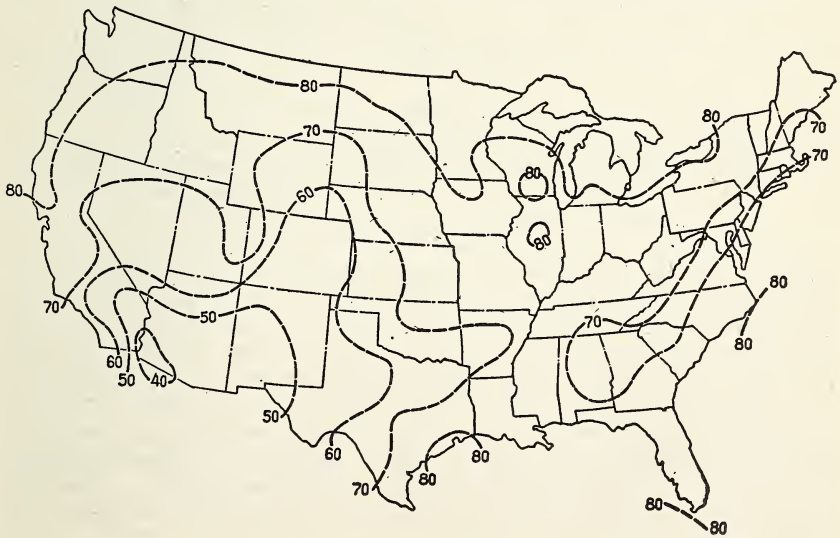


FIGURE 2.—Percentage of average relative humidity in January.

peratures within all zones change with altitude, being about 1° lower for each 400-foot rise above the average elevation.

Winter conditions are most severe in the northern part of New England and the northern parts of the North Central and the Mountain States, for temperatures are low, relative humidities high, and hours of winter sunshine few; also the snowfall is greater than in other sections and the winter feeding season is longer. In these areas there may be periods of several days when the weather is too severe for cows to be outdoors. Where there is more sunshine, doors and windows may be opened more freely and livestock may be kept outdoors during the day. In the Southeastern States and along the west coast, animals must have shelter from cold rains and winds, though winter temperatures are moderate. In summer, especially in the South, cows need protection from summer heat, as discussed more fully under Environmental Requirements (p. 9).

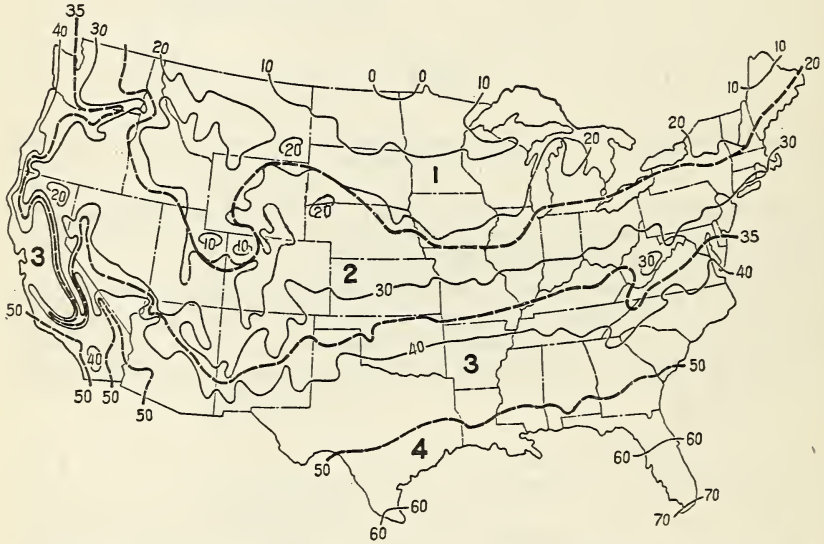


FIGURE 3.—Average January temperatures (° F.) and temperature zones.

## Local and State Health Regulations

Local and State regulations regarding quality of milk that may be sold within a city or other area usually include requirements affecting barn design and maintenance. Therefore, any person planning the design of a barn for the production of milk for market should make sure that the building will meet the requirements of the authorities where the milk is to be sold. In some cases local regulations differ from State regulations and from the recommendations of the State agricultural experiment station. The requirements here outlined should assist in obtaining such adjustments that greater uniformity of regulations may be obtained and all necessary sanitation provided at reasonable cost.

## Location of the Dairy Barn

The dairy barn should be located near a plentiful supply of good water on a well-drained site where prevailing winds will not carry barn odors to the dwelling and where odors or drainage from hog lots or manure piles will not be carried to the dairy barn or milk house. A site should be selected that will minimize the risk of fire spreading from building to building. If the barn is to be enlarged later it should be so placed with relation to other buildings that it can be extended at one or both ends. Where local health regulations require washing the stable floors, a large quantity of wash water must be disposed of and the site should be selected with a view to easy disposal.

Setting the long axis of a dairy barn north and south lets sunlight and air enter from both sides. In bank barns the upper part of the basement walls should not be in contact with the earth. An areaway at least 3 feet wide and 6 inches lower than the window sills should be provided to carry off surface water and to provide windows and vents in all four walls. The bank can be protected from erosion by a retaining wall or a terraced slope. Waterproofing the wall below grade, laying tile drains around the barn footings, and diverting water from uphill slopes make for a dry stable. A bridge across the areaway provides access to the mow. Local health regulations should be consulted for requirements affecting location of the dairy barn and milk house.

## Systems of Stabling Dairy Cows

Two general systems of stabling dairy cows are in common use—the stall barn; and the milking-room and lounging-barn combination. In the stall barn there is a stall or stanchion for each cow; sometimes individual pens are used instead of stalls, but barns of such type should not be confused with lounging barns. In winter the cows are kept in their stalls except for short exercise periods, and practically all feeding is done there; in warm weather the cows are outdoors except at milking time.

When the milking-room and lounging-barn combination is used, the cows are brought into the milking room in relays and remain there only while fed concentrates and milked. The rest of the time they are loose in the pasture, feed lot, or lounging barn, which serves as a shelter and a place to feed roughage in bad weather. Since the cows do not lie on a hard platform between other cows, swollen joints, injured udders, and similar troubles are reduced. In zones 1 and 2, however, lounging barns require 15 to 25 pounds of bedding per cow per day against 8 to 12 for stall barns, and where there is a lack of straw or other litter, stall barns are used almost entirely; in some areas regulations oppose the use of the lounging barn.

In either type of design provision must be made for storing feed and bedding and for accommodating calves, heifers, dry cows, calving cows, and generally a bull. A milk house also must be provided if more than a few cows are kept. This should be close to and preferably attached to the milking stable if regulations permit, but not opening into it. In zones 1 and 2, when all facilities are included,

there is little difference in total cost of buildings for the two systems and the total labor requirements are about equal.

Where the weather is mild or dry, little shelter is required for livestock and only small quantities of feed and bedding need be stored. Here the milking-room and lounging-barn combination has advantage from the standpoint of cost and adaptability to changes in size of herd.

## STALL-BARN DESIGN

Stall barns may be one or more stories in height, depending upon the storage space needed for hay and straw and whether the main hay storage is in a loft above the stable or in a separate building. Storage of hay and straw in one or more separate buildings has definite advantages from the standpoint of fire safety for the animals. While no figures are available as to actual labor requirements or relative cost of construction, it appears that there is little difference between loft and separate storage where baled or chopped hay is used. If loose hay is fed probably the least labor and cost are involved when the hay is stored in a loft and thrown down chutes into the stable. There have been many disastrous fires in barns constructed with this latter arrangement, and it is desirable for the safety of the livestock to use fire-resistant construction for stable walls and mow floor and to fit hay chutes with self-closing doors to reduce the danger of smoke from burning hay suffocating animals in the stable. Such an arrangement would insure longer time to remove the animals.

### Stable Arrangement and Width

Stall barns for 10 cows or less usually have the stalls in a single row, while barns for 10 to 40 or more cows usually have two rows. Ordinarily not more than 80 to 100 cows are placed in one building. Stables for more than 50 cows should be divided by a cross partition near the center to reduce drafts and stiffen the building. The stable may be so arranged that the cows face out or face in as preferred. When the cows face out, closer supervision of help is feasible during milking periods, the walls are not splattered with manure, and it is possible to save labor by driving a wagon or manure spreader through the central alley when cleaning the stable. Feeding, however, is easier when the cows face in.

A 32-foot barn with 8-inch walls can be remodeled as a two-row barn for small cows by using sweep-in mangers. The width of a new barn is determined by adding together the appropriate dimensions for feed alleys, mangers, stalls, gutters, litter alleys, and walls.

A barn 32 feet 8 inches inside width (34 feet outside if walls are 8 inches thick) permits use of high-front mangers and stalls for small cows.

A barn 34 feet 8 inches inside width (36 feet outside if walls are 8 inches thick) permits use of high-front mangers and stalls for medium-sized cows.

A barn 36 feet 8 inches inside width (38 feet outside if walls are 8 inches thick) permits use of high-front mangers, 5-feet 8-inch stalls,

and 18-inch gutters for large cows. The wider barns are adaptable to more varied uses in case of changes in farm management. Where a single-row, one-story barn is used it is advisable to make the width half that of a two-row barn and to use a shed roof. This will permit of future expansion into a standard two-row barn by adding a shed of equal width and having a common ridge with the first section.

Small herds are frequently housed in a general-purpose barn, but a tight partition separating the dairy herd from other stock is desirable. Health regulations in some areas prohibit location of pens for other stock in the same space with milk cows.

## Environmental Requirements

The following stable temperatures are considered satisfactory for average conditions in winter in the designated zones. (See fig. 3.)

| Zone: | *Stable temperature in winter (° F.)* |
|---|---|
| 1 | 35 to 45 |
| 2 | 40 to 50 |
| 3 | 45 to 55 |

Stable temperatures should not fall below freezing even on the coldest days; relative humidity in stables should not exceed 75 percent under average weather conditions or 85 to 90 percent on extremely cold days.

In zone 4 control of stable temperature and relative humidity is not important in winter, though shelter must be provided against cold winds and rain. During periods of high temperature and high relative humidity milk production is low, and at such times special attention should be given to keeping cows comfortable. Shade provided in the pasture and by the barn, protection from flies, and unrestricted air movement through the stable are means of reducing losses in milk production in hot weather.

## Ventilation of Stables in Winter

The need for controlled ventilation to regulate the temperatures of stables and to avoid sudden extreme fluctuations increases with the severity of winter conditions. In zones 3 and 4 and in parts of zone 2 having 6 hours or more of winter sunshine daily, windows and doors are usually effective means of ventilation. Windows tilting in at the top and having cheeks to reduce drafts are widely used. In a warmly built barn (see Insulation, p. 11) controlled ventilation may be obtained by use of electric fans or by outlet flues operating by gravity. Inlets are needed with either type of system.

The total inlet area for a gravity system may be about two-thirds the total outlet flue area. With a fan system there should be an inlet for about every 3 cows. Inlets usually have a cross-sectional area of not more than 60 square inches and are spaced uniformly around the stable, but not within 5 feet of an outlet or a corner of the building. Inlet ducts should be designed for avoiding direct entrance of wind or back drafts and for insulation on the warm side. Inlets should be protected by hoods on the outside and be equipped with dampers.

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Data on heat and vapor emitted by cows, adapted from Armsby and Kriss,[3] are given in table 2. The temperature of the calorimeter in

TABLE 2.—*Heat and vapor emitted by typical dairy cows*

| Breed | Total heat emission per hour [1] | Water vapor produced per hour |
|---|---|---|
| | *B. t. u.* | *Pound* |
| Jersey cow: | | |
| Producing 30 pounds of milk | 3,000 | 0.71 |
| Producing 20 pounds of milk | 2,700 | .64 |
| On maintenance | 1,600 | .38 |
| Holstein cow: | | |
| Producing 45 pounds of milk | 3,700 | .87 |
| Producing 30 pounds of milk | 3,300 | .78 |
| On maintenance | 2,000 | .48 |

[1] Includes latent heat of vaporization.

which the measurements were made was about 65° F. The quantity of water vapor produced by cows at lower stable temperatures is probably less than at 65° and the heat produced greater; but no information is available on the moisture evaporated from mangers, gutters, and washed surfaces in the stable. Experimental work is needed to obtain complete data on the heat and moisture emitted by cows and on the heat and moisture losses from floors and walls under typical winter conditions.

## GRAVITY VENTILATION

Gravity systems of ventilation may be used with either one- or two-story barns but they work best with high outlet flues and when a large difference exists between stable and outside temperature. The size of outlet flues may be determined by the formula $A=\frac{163+1.6\ t_o}{\sqrt{H}}$, when $A$ = square inches of flue per 1,000-pound-cow-unit; $t_o$ = local mean January temperature; and $H$ = height in feet of top of flue above stable floor.[4]

Opinions differ as to number of outlet flues needed. Some engineers recommend only one flue in a barn up to 110 feet in length (50-cow size), while others limit the size of each flue to about 300 square inches and use as many as needed to give the required total area; still others recommend one outlet to every 30 to 35 feet in length of barn. Opinions differ as to whether air should enter the outlet flues at the

[3] See Selected References (*1*), p. 23.

[4] *Example:* How much outlet flue area is required for a barn near St. Paul, Minn., housing thirty 1,200-pound cows, six 300-pound calves, and one 2,000-pound bull; flue height above floor 36 feet?

*Solution:*

(1) From figure 3, the mean January temperature ($t_o$) at St. Paul is +10° F.; $H=36$.

$$A=\frac{163+(1.6\times 10)}{\sqrt{36}}=29.8 \text{ square inches per 1,000-pound-cow unit.}$$

(2) 1,000-pound-cow units:

| | *Pounds* |
|---|---|
| 1 bull = | 2,000 |
| 6 calves at 300 pounds = | 1,800 |
| 30 cows at 1,200 pounds = | 36,000 |
| | 39,800 = 39.8 1,000-pound cows. |

(3) Total outlet flue area = $29.8\times 39.8=1{,}186$ square inches.

ceiling or near the floor. When outlet flues extend below the ceiling, additional openings are provided at the ceiling for use in warm weather. Outlet flues should be well insulated and should extend well into the throat of the cupola and be provided with dampers for controlling the flow of air. The relative advantages of the various arrangements are stated in publications listed on page 23.

### MECHANICAL VENTILATION

Electric-fan ventilation has one important advantage over the gravity system—air change can be controlled regardless of inside and outside temperature difference, wind, or height of barn. The combined capacity of all fans in a stable should be 70 to 100 cubic feet per minute per 1,000 pounds of livestock. The thermostatically controlled fan provides an automatic ventilating system that requires little attention, but it should permit manual control. Differences of opinion as to whether outlets should be arranged to remove air from the floor level or take it from the ceiling apply to fan as well as gravity ventilating systems.

Changing weather conditions put different loads on ventilating systems, and it is considered advisable to provide for some ventilation most of the time rather than much ventilation at infrequent intervals. The use of two or more fans or one fan with two or more speeds is therefore recommended.

## Insulation

Insulation of stables has two purposes: (1) To avoid condensation of moisture where it will cause damage; and (2) to maintain comfortable temperatures for cows and workers and at the same time permit adequate ventilation. The insulating values [5] shown in table 3 are suggested for dairy barns in zones 1, 2, and 3.

Table 3.—*Suggested minimum insulating values*[1] *for dairy stables*

| Stable size | Zone 1 | | Zone 2 | | Zone 3 | |
|---|---|---|---|---|---|---|
| | Walls | Ceiling | Walls | Ceiling | Walls | Ceiling |
| Large | 4.0 | 7.0 | 3.0 | 5.0 | 2.0 | 3.5 |
| Small | 6.0 | 7.0 | 4.0 | 5.0 | 2.0 | 3.5 |

[1] See footnote 5, below.

These minimum insulating values should be increased by 1 or 2 units in the colder parts of the zones or if the building has an unusually large exposed surface in proportion to the number of animals housed. A stable having the insulating values indicated in table 2 should be free of condensation on the ceiling except in the coldest weather, provided it is full of stock and the animal heat is well distributed.

[5] The insulating value represents the number of degrees difference in temperature on opposite sides of a wall that will cause 1 B. t. u. of heat to flow through an area of 1 square foot in 1 hour.

The insulating values of common types of construction are given in figure 4. Insulation should be protected from mechanical damage by a thickness of boards, sheet metal, plaster, or other hard, strong material.

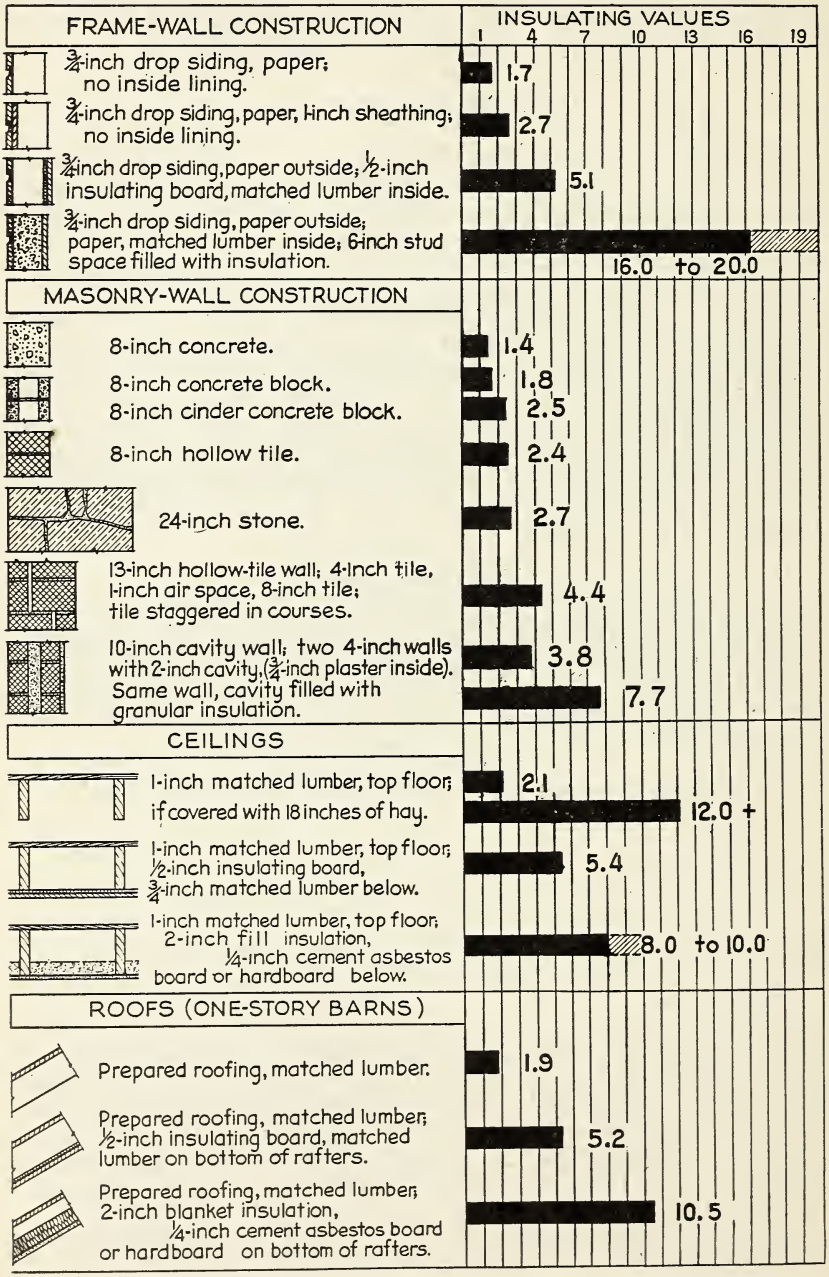


FIGURE 4.—Insulating value of common types of construction. For definition of "insulating value" see footnote 5, page 11.

To prevent circulation of cold air in the joist spaces in a two-story barn with ceiling below the mow joists, these spaces should be blocked at the outer walls unless the ceiling is insulated with fill insulation.

Storm windows and double-thick doors or storm doors to conserve heat are recommended for all sides of the barn in zone 1 and for the most exposed sides, usually the north and west, in zone 2.

### VAPOR BARRIER

A vapor barrier is needed on the warm side of fibrous or fill insulating materials to prevent water vapor in the moist stable air from condensing in the insulation. The vapor barrier may be shiny, heavily asphalted paper, aluminum foil, lightweight roll roofing, or similar material, or two coats of asphalt, or aluminum-flake paint. Tarred felt, red resin paper, or ordinary paint is not satisfactory. Unless the vapor seal on commercial insulation is guaranteed to stand up under continued exposure to high humidity, one of the above barriers should also be used. Spaces packed with fill insulation should be vented on the cold (outer or upper) side to permit "breathing" and to assist in the drying out of moisture that might penetrate through the barrier. Where there is no ceiling and insulation is supplied by the hay in the mow there should be a vapor barrier between the joists and the floor boards.

## Floor Space

### COW STALLS

The dimensions of cow-stall platforms should be varied to suit the size of the animal and to make for comfort and cleanliness. Table 4 and figure 5 give dimensions that have been generally used for several years. There is a tendency to breed and select dairy cows for greater size, however, and also to allow more width in stalls in order to reduce injury to udders. For high-producing cows or where cost of barn is not a primary consideration it may be desirable to increase by 6 inches the width of stalls for cows of the larger breeds. For very large cows both length and width of platform and width and depth of gutter may have to be increased. More information on this

TABLE 4.—*Usual dimensions for cow stalls*

| Breed | Stall width [1] | Stall length (S)[2] for— | | | Stall partition | | Gutter width (G)[2] |
|---|---|---|---|---|---|---|---|
| | | Small cows | Medium-sized cows | Large cows | Length (P)[2] | Height (H)[2] | |
| | *Ft. In.* | *Ft. In.* | *Ft. In.* | *Ft. In.* | *Ft. In.* | *Ft. In.* | *Inches* |
| Holstein-Friesian | 3 6 to 4 0 | 4 10 | 5 2 | 5 8 | 3 6 | 3 6 | 18 |
| Brown Swiss | 3 6 to 4 0 | 4 10 | 5 2 | 5 8 | 3 6 | 3 6 | 18 |
| Shorthorn | 3 6 to 4 0 | 4 8 | 5 0 | 5 6 | 3 6 | 3 5 | 18 |
| Ayrshire | 3 6 to 4 0 | 4 6 | 4 10 | 5 4 | 3 6 | 3 5 | 16 |
| Guernsey | 3 6 to 3 8 | 4 6 | 4 10 | 5 2 | 3 6 | 3 5 | 16 |
| Jersey | 3 4 to 3 6 | 4 4 | 4 8 | 5 0 | 3 3 to 3 6 | 3 4 | 16 |

[1] Width is from center to center of partitions.
[2] Symbols used appear in figure 5.

subject is needed. The length and width of stalls in one or both rows may be varied to accommodate large and small cows in the herd. Small changes in length of stall are readily made by adjusting the position of the stanchion, but the width is not adjustable. When chain ties are used in place of fixed stanchions, the stalls should be constructed in accordance with the equipment-manufacturer's specifications. In face-out barns it is advisable to fasten the stall partition to the girder post to eliminate the hazard of a cow breaking her leg between the two.

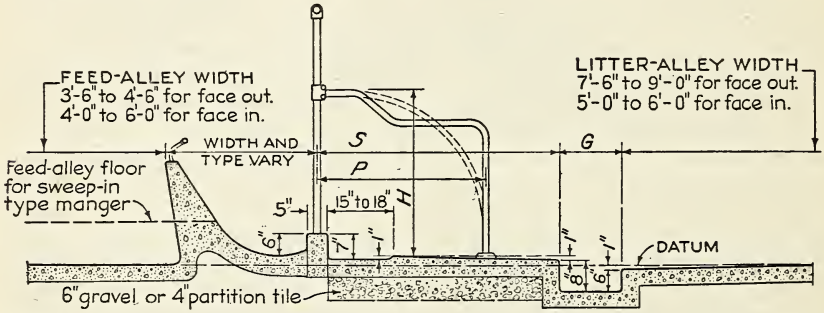


FIGURE 5.—Section showing typical cow stall: S, stall length (length of cow from shoulder to tail plus 6 inches); P, partition length; H, partition height; G, gutter width.

## PENS

The size of animals should be considered in deciding on the size of pens. Where only one or two pens are to be provided they should be at least 12 by 12 feet. For a number of calves in one pen allow for each a minimum of 20 square feet and 20 to 25 inches for manger space. When special pens are desired the sizes shown in table 5 are suggested.

TABLE 5.—*Size and height recommended for special pens*

| Type of pen | Size | Height |
|---|---|---|
| | *Feet* | *Ft. In.* |
| Bull | 10×12 to 12×16 | 5 3 |
| Test cow | 9×10 to 12×12 | 4 6 |
| Maternity | 10×12 to 12×12 | 4 6 |
| Individual calf | 4×6 to 6×6 | 3 9 |

Individual calf pens having slatted or wire platforms raised several inches above the pen floor aid in keeping calves healthy. In zones 1 and 2 pens that are not in the dairy stable should be close to dry cows, horses, or other animals that will furnish warmth; otherwise, artificial heat may be needed in very cold weather.

Hospital and maternity pens should be in another building or separate from the milking stable where possible. Locate gate and mangers in maternity and test pens so that attendant can enter pen on right-hand side of cow when at manger. Construct pens so they can be easily cleaned and disinfected, provide solid curbs 6 inches high between pens and at alleys, and drain washings from pen through a hole in alley curb.

Bulls should be housed in a separate room or building so that the exterior door, which allows free access to outside paddock or yard, will not permit cold air to enter the dairy stable.

### ALLEYS

Feed alleys, with cows facing out, should be 3 feet 6 inches to 4 feet 6 inches wide, exclusive of mangers; with cows facing in, 4 to 6 feet, exclusive of mangers. The wider feed alleys are desirable where sweep-in mangers are used. Litter alleys, with cows facing out, should be 7 feet 6 inches to 9 feet wide, exclusive of gutters; with cows facing in, 5 to 6 feet, exclusive of gutters.

Where feed trucks are used, cross alley should be not less than 3 feet 6 inches wide. To find the width needed for turning an ordinary feed truck, subtract the width of feed alley from 8 feet 4 inches; the remainder is the width of the cross alley. Curving the end of the manger or using a short feed truck will permit the use of narrower cross alleys.

### CEILING HEIGHTS

In cold climates, the ceiling should be 7 feet 6 inches to 8 feet; in moderate climates, 8 to 9 feet; and in warm climates, 8 feet 6 inches or more. Where litter carrier track crosses under a girder allow a minimum clearance of 6 inches below bottom of girder for carrier trolleys.

## Details of Design

### FOUNDATIONS

Foundation walls of concrete or masonry for frame superstructures should extend at least 12 inches above the alley floors. Footings should be below frost action and not less than 2 feet below grade to give protection against damage by wind, erosion, and trampling of animals; spread footings are advisable. Provide ample anchorage for frame superstructures. Foundations for wood posts should extend at least 4 inches above the floor.

### FLOORS

Floors of concrete or other suitable impervious material that may be readily cleaned are required in a barn where milk for market is produced and are desirable in any stall barn. All floors used by the cows, including stall platforms and box stalls, should be sloped to a drain or gutter and be finished with a wood float or otherwise roughened to prevent cows slipping, yet permit easy cleaning.

A 6-inch bed of gravel or crushed stone or 4-inch partition tiles under the floor of cow stalls and pens raises them above grade and helps to retard rise of capillary moisture from the earth. Cinders are likely to corrode metal pipe.

### GUTTERS

The dimensions for gutters shown in figure 5 and table 4 are generally acceptable when cows are kept in the barn overnight. For very large cows or if mechanically operated cleaners are to be used,

wider and deeper gutters may be needed. Sides and bottoms should be troweled smooth for easy cleaning and upper corners rounded slightly. Gutters with vertical sides lessen splattering of manure. Where gutters are provided with drains, slope bottom of gutter ½ inch per 10 feet; in long barns slope gutter two ways to drain. Sometimes the whole floor is sloped to get gutters of uniform depth. Too great a slope allows liquid in gutter to form into pools around droppings. A common practice is to cap gutter drains and use them only for flushing water when cleaning the stable, and to use bedding to absorb liquid manure. (See also Disposal of Drainage, p. 21.)

### MANGERS

A high-front manger is more sanitary than the sweep-in type and eliminates knee injury to cows reaching for feed in the alley, but is more expensive to construct. The interior of mangers should be troweled smooth and all angles rounded. The over-all width of the high-front manger is about 3 feet and the width of the sweep-in type varies from about 22 to 30 inches.

### WALLS AND CEILINGS

In addition to being properly insulated and vapor-proofed where conditions require, the walls and ceilings should be easy to keep clean. Where milk for market is produced, local authorities often specify that walls and ceiling be provided with a smooth dust-free surface. Interior illumination is increased if the ceiling and side walls are white or light in color. Oil or cold-water paints are preferable to whitewash, because of less flaking.

In the South many dairymen prefer and some local regulations permit open-wall construction 4 feet above the floor; however, means for closing the openings in stormy weather are desirable.

### WINDOWS

An area of 4 square feet of glass per cow or 1 square foot per 20 square feet of floor area uniformly distributed on both side walls has been commonly accepted as needed for barns; however, in northern regions 3 to 3½ square feet of glass per cow is now considered sufficient. Window sills 4 feet above the floor in alleys and 5 feet in pens reduce glass breakage. (For information on storm windows and doors, see p. 13.)

### DOORS

Single-door openings should be 3 feet 6 inches to 4 feet wide and double doors 6 to 8 feet wide; a door between 4 and 6 feet in width is wider than needed for passage of one cow at a time but too narrow for two cows. Doors for bull pens should be 4 feet; the minimum width of openings for drive-through barns is 8 feet. Hinged doors or overhead-lift doors are recommended for cold regions, as they can be made more weathertight than sliding doors.

Hay doors should be 9 to 11 feet wide and 10 to 14 feet high where a fork is used, and 11 to 12 feet wide and 11 to 15 feet high where slings are used. When litter carriers are installed, provide removable

track section for single sliding door and a hinged panel over hinged single doors. Second-floor driveway doors should be 12 by 12 feet or larger; provide a dormer over the door to give head room if side walls are less than 13 feet above mow floor.

## MILKING-ROOM AND LOUNGING-BARN COMBINATION

The milking room is the more important unit of the milking-room and lounging-barn combination and should be designed, equipped, and located to meet all sanitary requirements of the area where milk is to be sold. The cleanliness of the cows when in the lounging barn, however, has an important bearing on the quality of the milk produced. Cows can be kept as clean in a lounging as in a stall barn, provided the lounging barn is properly arranged, the space per cow is adequate, and enough bedding is provided. Since lounging barns operate much more successfully where manure is allowed to accumulate to a considerable depth, the dairyman before deciding to install a lounging barn should make sure that the dairy inspector will permit such accumulation. Daily cleaning of a lounging barn would greatly increase both the labor requirements and the quantity of bedding needed, thus making it more difficult to keep the cows clean and depriving them of a soft warm bed.

### Milking Rooms

Any of three systems—the "walk-through," the "back-out," and the "tandem"—may be used for the milking room in a detached building, in a room attached to the barn, or in a partitioned-off room inside the lounging barn.

In the walk-through type the cows are brought in through an entrance door in relays, placed in stalls, milked, then freed by opening the front gate of the stall and having them pass through the exit door into a field or barn pen separated from the one where the unmilked cows are being held.

The back-out type is really a small one-row stall barn used only for milking. In the tandem type the stalls are arranged one in front of the other with an alley on one side and a working space on the other. The cows enter and leave the stalls through gates at the alley side of each stall and do not pass through the working space, which is reserved for the milkers.

A small feed-storage room is needed if cows are fed concentrates when being milked. A washroom is desirable for the milkers if one is not provided in a nearby milk house; sometimes the milk house is combined with or attached to the milking room. A room may be provided for washing cows before they are milked.

#### SPACE REQUIREMENTS

Usually the cows are milked in relays so that a large herd can be milked in 8 to 12 stalls; 2 to 4 stalls are generally provided for 10 to 30 cows. Stalls should permit either hand or machine milking. For 3-minute milking, during which cows are fed grain, 4 stalls should be provided for each single-unit milking machine. An 8- to 12-stall

milking room is most effective for fast milking when concentrates are fed.

The length of walk-through stalls should be about 24 inches greater than that shown in table 4, and the length of tandem stalls about 2 feet 6 inches greater. Width of stalls may be slightly less than in the stall barn. The width of alleys behind walk-through or back-out stalls should be 5 to 7 feet. For tandem stalls the side alley should be 3 feet to 3 feet 6 inches.

#### DETAILS OF DESIGN

The construction of floors should be the same as in stanchion barns. The gutters should be 16 inches wide and 4 inches deep, pitched 1 inch in 10 feet to the drain. Where a gutter is not to be used, the floor should be pitched to drain for flushing.

#### OTHER DETAILS

Requirements for wall and ceiling surfaces, window areas, electric lighting, and water supply for washing cows and floors are substantially the same as for stall barns. The walls, however, at least to window-sill height, should be of a material that can be washed. The walls and ceilings should be smooth and free of ledges and offsets that might collect dust. Watering devices for the cows are not needed in the milking room. Windows and doors usually are depended upon to furnish sufficient ventilation.

#### TEMPERATURE CONTROL

In cold climates attention must be given to keeping the temperature of the milking room above freezing, chiefly for the comfort of the milkers and for protection to the plumbing. Insulation reduces the cost of heating. A standard chimney, with a spark arrester and so located that sparks will not reach hay or bedding, and other proper safeguards against fire must be provided where solid fuel is burned for heating the building or water, especially if the milking room is inside the barn. If location permits, heat may be supplied from the heater in the milk house.

### Lounging Barns

The lounging barn, also called by a variety of other names, provides shelter and feeding facilities for cows between milkings. The cows are not confined in stalls but are free to move around in the barn and generally have free access to pastures or lots.

Lounging barns may be either open or closed buildings of one or two stories, depending on climate and arrangement for storing hay and feed. Storage requirements are substantially the same as for stall barns. Where the lounging barn is used in areas of little winter rainfall, however, it is common practice to feed hay and silage outdoors, preferably in the lee of a windbreak. In the coldest areas the lounging barn should be fully enclosed or have doors and windows that may be shut during a storm. Where bad weather may last for

several days at a time, provision for ventilation by flues or electric fans is desirable. In milder areas the lounging barn may be open on the south or east. In the warmest areas a shed with walls on only the two windward sides may be used; these walls should have large openings fitted with doors or panels that can be closed in winter and opened to allow maximum ventilation in warm weather.

### SPACE REQUIREMENTS

The floor space, in addition to that needed for troughs and pens, should be sufficient to prevent overcrowding, with an allowance of 60 to 80 square feet per cow, depending on the breed. (See table 4 for relative sizes.) Where a lounging barn is used all cows should be dehorned. In two-story buildings a 9- to 10-foot ceiling allows needed height for manure accumulation. The lounging barn should be so arranged that milked and unmilked cows can be kept separate during milking. Sometimes it is divided into several pens. Wide doors in the ends of the barn and movable pen partitions permit a manure spreader or wagon to be driven through the barn for removing manure.

Open sheds used as lounging barns in the milder areas are preferably 24 to 26 feet wide, but not less than 20 feet, to provide a dry place for the cows in stormy weather. A height of 8 feet at the back will allow for the accumulation of manure and bedding. To obtain proper roof slope a 24-foot shed should be 13 to 15 feet high at the front. A shed roof, if used, should slope to the rear. If gable roof is used, a gutter at the front will keep rain water runoff out of the feed lot.

### DETAILS OF DESIGN

Foundations should be of concrete or masonry carried to a height of 4 feet above the floor, so that manure will not come in contact with the superstructure. The ground outside should be graded to shed water away from the building. Footings and anchorages should be the same as for stall barns.

Floors of well-tamped clay sloping down from the back can be used in the lounging barn, but to prevent holes being worn where the cows stand while eating, a concrete platform 6 to 8 feet wide may be built next to the manger. Where rainfall is heavy or in poorly drained locations, part of the floor or of the outside yard may be paved.

Partitions for pens should be about 4 feet 6 inches high and adjustable to allow raising them 3 feet as manure and bedding accumulate. They may also be made movable to permit increasing or decreasing the size of the pens to suit the number of animals. At least two pens are needed, to separate milked and unmilked cows.

Mangers should be of tight construction for feeding silage, about 30 inches wide, and approximately 30 inches high from the floor, to allow for the accumulation of manure. The feed rack should be placed above the manger so that the hay will not be wasted on the floor. The length of manger and feed rack allowed for each cow in a pen should be 3 to 5 feet in zone 1 or 2 to 2½ feet in areas where part of the feeding is done outdoors.

## FEED STORAGE

Bedding-storage capacity in the northern areas may amount to 2 tons per cow for lounging barns and three quarters of a ton for stall barns.

Hay-storage capacity, where no silage is fed, varies from 2 to 3 tons per cow in zone 1 to less than 1 ton in regions having a long pasture season. If silage is fed, the capacity may be reduced in accordance with the feeding plan. Covered storage is desirable in humid and cold areas, but in areas of little rainfall a large part of the hay may be stacked and fed in the open.

Hay chutes should be provided with tight trap doors to permit proper functioning of the ventilation system, conserve heat, avoid condensation of moisture in the haymow, and prevent rapid spread of fire; devices for automatic closing are desirable. A slatted chute from mow floor to full height of mow permits throwing down hay when the mow is full and is an indispensable safety measure. In a face-out barn with loft, have the chutes between windows, so that hay will not catch on sash when window is open. Local regulations sometimes require that hay chutes open into the feed room.

Storage capacity for grain and other concentrates varies from space for a truckload of feed for the herd to a ton or more per cow where grown on the farm. A feed room on the ground or mow floor with two or more bins and space for grinding and mixing feed is desirable where a separate granary is not available. When the feed room is on the ground floor, a dusttight partition should separate it from the stable. Feed-room floors should be ratproof and dry.

The required storage space may be calculated from the following weights of feed and bedding.

| | *Pounds per cubic foot* |
|---|---|
| Loose hay: | |
| In shallow mows | 4 or less |
| In deep mows | 4½ or more |
| Baled hay: | |
| Loose bales | 10 |
| Ordinary bales | 12–14 |
| Very tight bales | 20–25 |
| Chopped hay | 8–12 |
| Straw (ordinary bales) | 10–12 |
| Shavings (baled) | 20 |
| Oats | 26 |
| Barley | 39 |
| Wheat | 48 |
| Corn (shelled) | 45 |
| Bran (loose) | 13 |
| Middlings (loose) | 25 |
| Linseed or soybean meal (loose) | 30–40 |

## SILOS

In selecting sites for silos consider convenience in feeding, accessibility to wagons or trucks for filling, and the future possibility of erecting one or more additional silos or lengthening the barn; do not place the silo too close to the milk house. In northern climates silos should be located where the sun shines upon them.[6] A permanent above-ground silo should open into an anteroom having a tight door to the barn and made large enough to store the silage truck.

[6] For further information on silos see McCalmont, in Selected References (*13*).

## WATER SUPPLY

A minimum of 15 gallons of water a day for each cow and an ample additional supply if cows, stables, and milking equipment are to be washed should be provided. Where drinking cups are used a minimum pressure of 3 pounds is needed. One cup will serve two cows when manger divisions are not used; an individual cup is advisable in each pen in a stall barn; the cup in the bull pen should be protected with a guardrail.

The hose hydrant or faucet and all other plumbing should be so placed that they will be protected from damage by carts, trucks, or freezing and will not injure cows; a floor drain under the fixture is desirable. Provide a stop-and-waste valve to the drainage system. Drainage openings at the end of mangers facilitate disposing of cup overflow and manger washings.

In lounging barns a water trough is usually provided; pipes and connections should be safeguarded against frost and other damage.

## LITTER DISPOSAL

Where temporary storage of manure is necessary, a covered fly-tight pit and often a liquid tank are desirable. Manure should be removed from stall barns at least once a day, and from milking rooms after each milking. Where practicable, it is desirable to haul it directly to the fields. In lounging barns the manure need not be removed until the head room is restricted or flies start to breed in it.

Litter carriers or wheelbarrows are commonly used, but in face-out barns a spreader, sled, or wagon may be driven through the barn. Where the clearance under girders is insufficient for litter-carrier tracks, a carrier tub can be handled on a floor truck inside the barn. The truck can be wheeled out onto a concrete pavement, where the tub is raised and conveyed on an outside track to the storage pit or emptied directly into the manure spreader.

### Manure Pits

The distance between the manure pit and the barn and milk house is specified by most local sanitary regulations. The size of a pit can be approximated by allowing for 1¼ cubic feet a day per 1,000-pound cow. Provide a pit large enough for storage during the part of the year when the manure cannot be hauled to the fields. The floor should slope toward the back to retain the liquid but not be too steep for backing in the spreader. Sometimes a tank for holding liquid manure is connected with the pit. The roof of the pit is often extended at the front as a shelter for the spreader when not in use.

### Disposal of Drainage

The composition of the drainage and washings varies with management practices in stabling and cleaning. Thorough shovel cleaning and sweeping reduce the quantity of solid matter washed out and of waste water to be disposed of. Much trouble with stoppage of drains can be eliminated if the lines under the barn floors are laid

straight, without bends, to a manhole and settling basin outside the barn, so that the line can be readily rodded and solid matter removed before it clogs the drain to the liquid-manure tank or place of disposal; sometimes screened filters can be used to remove solid matter. Gutter drains and traps should permit rodding.

A convenient size for a liquid-manure tank is 8 to 10 feet in diameter and in depth; frequency of emptying depends on the number of cows and the quantity of waste water drained into it; flushing water is often diverted in a separate line to another place of disposal. When it is not feasible to empty the tank by gravity a liquid-manure pump can be used.

When a liquid tank is not used for flushing water and topography permits, the effluent can be drained to a convenient locality some distance from the milking structures and spilled into a ditch, tiled field, or cesspool. The drain line to place of disposal should be of tile-drain pipe or a concrete-lined ditch, especially in warm regions, so that flies, mosquitoes, and odors can be controlled.

## LIGHTING

Sufficient light for the task to be performed should be provided in stall barns, milking rooms, lounging barns, and feed storages. Windows, as suggested on page 16, generally admit sufficient daylight into the stable. Windows or louvers of mows are best located high in the gables or in dormers, so as not to be blocked by hay. More light is needed in the feed room than in the stable, while stairways or ladders to mow and in the silo room should be well lighted to lessen accidents.

Artificial light is needed for work after dark and in spaces that cannot be lighted in the day by windows. Illumination can be increased by painting ceilings and walls white and keeping them clean; it is of interest that the light near white cows is 10 to 18 percent greater in intensity than that near black cows. Where electricity is available no other artificial light should be considered, for open flames and lanterns constitute a fire hazard. The wiring and all fixtures should be installed in accordance with the National Electrical Code.

In stall barns where cows are milked and in milking rooms, at least 1 footcandle is needed at the place of milking, while at least 2 footcandles are needed for reading an ordinary dairy scale when feed or milk of individual cows is weighed. In face-out barns good light is obtained with 60-watt lamps in a staggered arrangement, four stalls, or 16 feet, apart over each gutter—lamps in the right-hand row being two stall spaces ahead of those in the left row. Feed-alley lamps should be spaced 3 feet from the wall, every six to eight stalls, or 24 to 32 feet apart. About the same light should be provided for face-in barns, although additional light is reflected from nearby walls painted white. In some milk areas reflectors are not permitted, because they are seldom kept free of dust. Some dairymen use 100- to 150-watt lamps instead of 60-watt, since they feel that the increased light not only is an incentive to keep the barn cleaner but also results in the production of better milk.

Where lights are not provided over box stalls, double-convenience outlets nearby will permit the use of a trouble lamp or special elec-

trical appliance. Switches located beside an entrance door at each end are a convenience. A lamp not connected with the circuit of the main barn lights can be left burning in the barn all night. Dustproof globes are advisable for lights in the haymow and feed room. A high outside light operated by switches both at the barn and at the house is very convenient. Where necessary to handle cows outside, other lights are needed.

Lounging barns require artificial light for working in the areas where feed is handled and where cows are driven to the milking room; additional lights in the pens may be desirable.

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